University of BRISTOL

Evaluating drought responses in JULES at FR-Pue

From structural calibration and stomatal optimisation

To model transferability and hydraulic legacy

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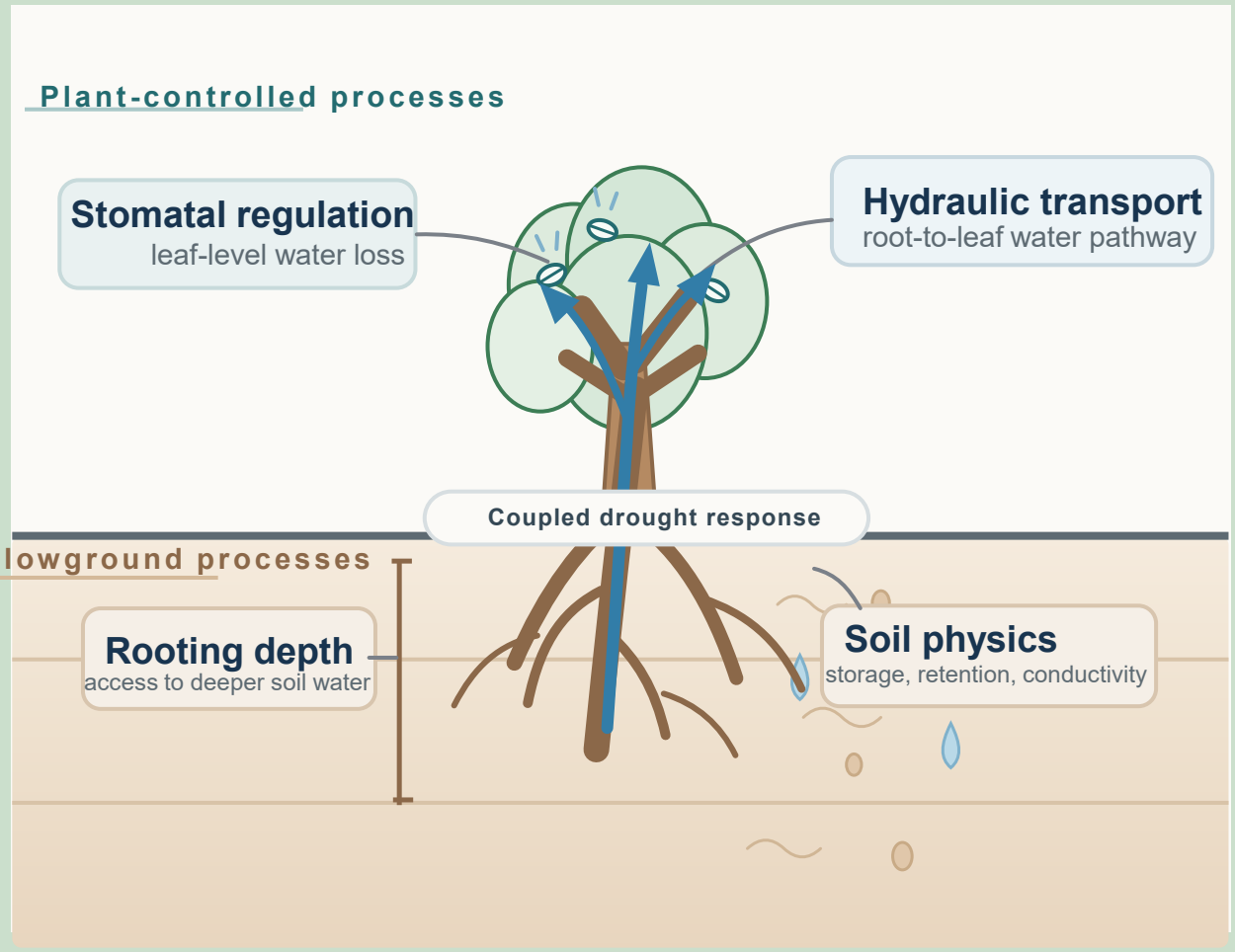
Background

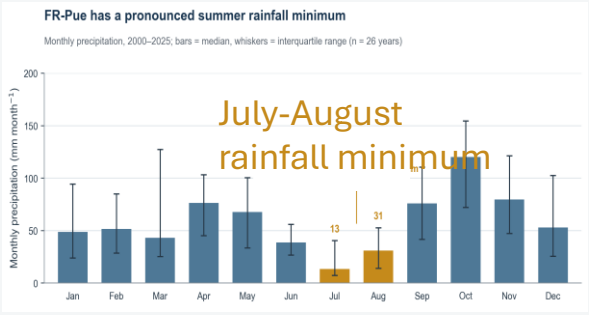


Coupled controls make evaluation difficult when direct observations are limited

1 | Observed data

FR-Pue / Puéchabon

Mediterranean oak forest
Southern France
Recurrent seasonal drought



Flux (2000-2025)

- GPP
- raw LE
- LEcorr

Water statu

- Ψleaf
- Soil water content

2 | Models used

JULES Baseline

- **STD-OOB**

(Standard JULES: out-of-box baseline)

- **PM-OOB**

(Profit-max stomatal optimisation out-of-box baseline)

Soil depth and layering
Soil parameters: b, sathh, sm_sat
Photosynthetic : vsl
Root zone water potential: root_psi_crit

Control soil structural and parameters

- **STD-TUNED**
- **PM-TUNED**

New hydraulic legacy model

- **PM-XI (Xylem impairment)**

Research questions

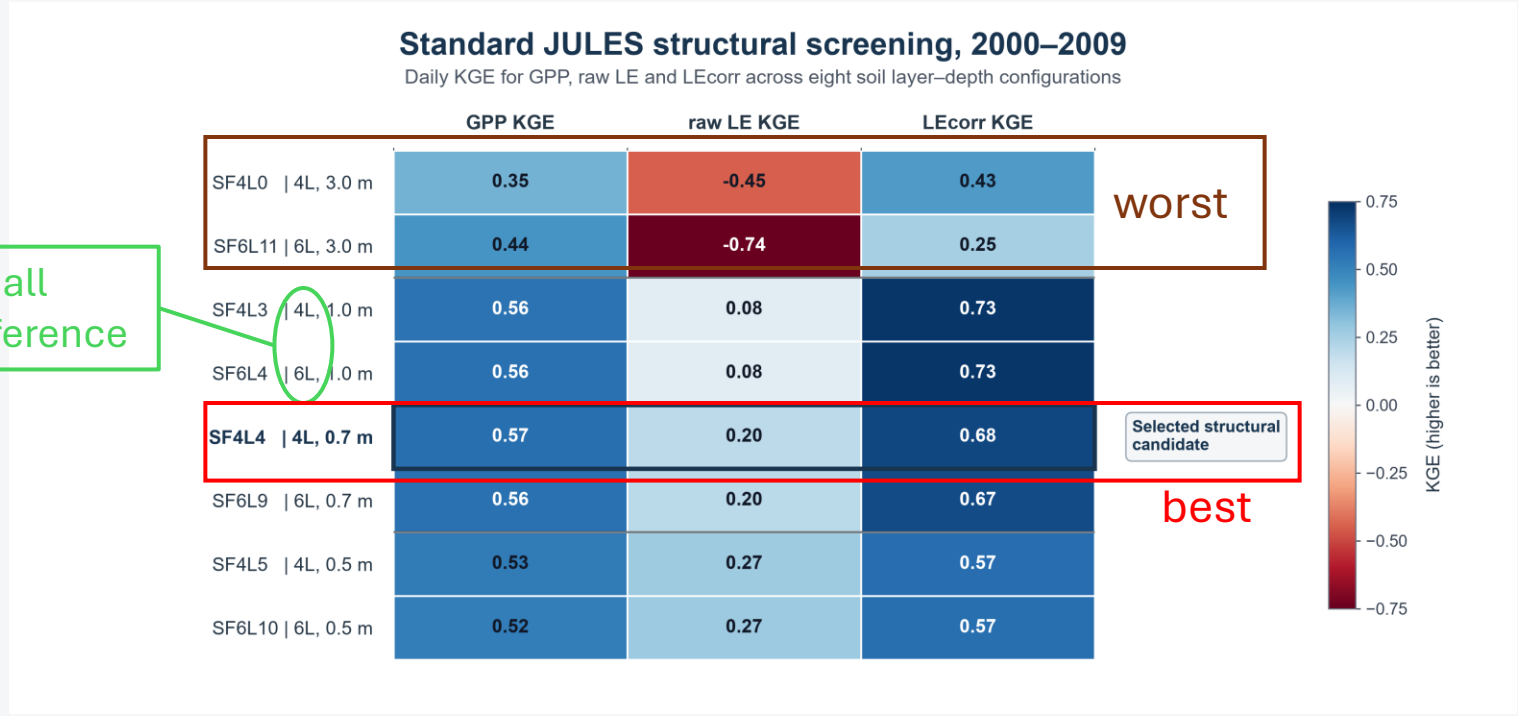
1. **How much can model bias be reduced?**
   How much can bias be reduced by constraining belowground structure and key parameters?
2. **Does stomatal optimisation add value beyond calibration?**
   Does Profit-Max improve predictions of drought fluxes beyond calibration?
3. **Are improvements for the right reasons?**
   Do improvements arise from more realistic physiological responses?
4. **Can the calibrated model predict a more severe drought?**
   Can JULES simulate a more intense rain-exclusion experiment it was not calibrated for?
5. **Can hydraulic legacy effects improve drought predictions?**
   How do previous summers influence ecosystem responses in current summer?

1 How much of the bias can be reduced by constraining belowground structure and key parameters?

Result: Soil structure calibration

STD 8 soil layer–depth configurations | daily GPP(GPP-prioritised), raw LE and LEcorr | 2000–2009 calibration period

1 | Structural screening



2 | Summary

Main pattern

- 3 m: perform worst
- 0.7 m: higher overall skill
- 4 vs 6 layers: small differences within same depth

Result

- Constraining soil-column depth removes much of the baseline bias;
- layer-number effects are comparatively small.

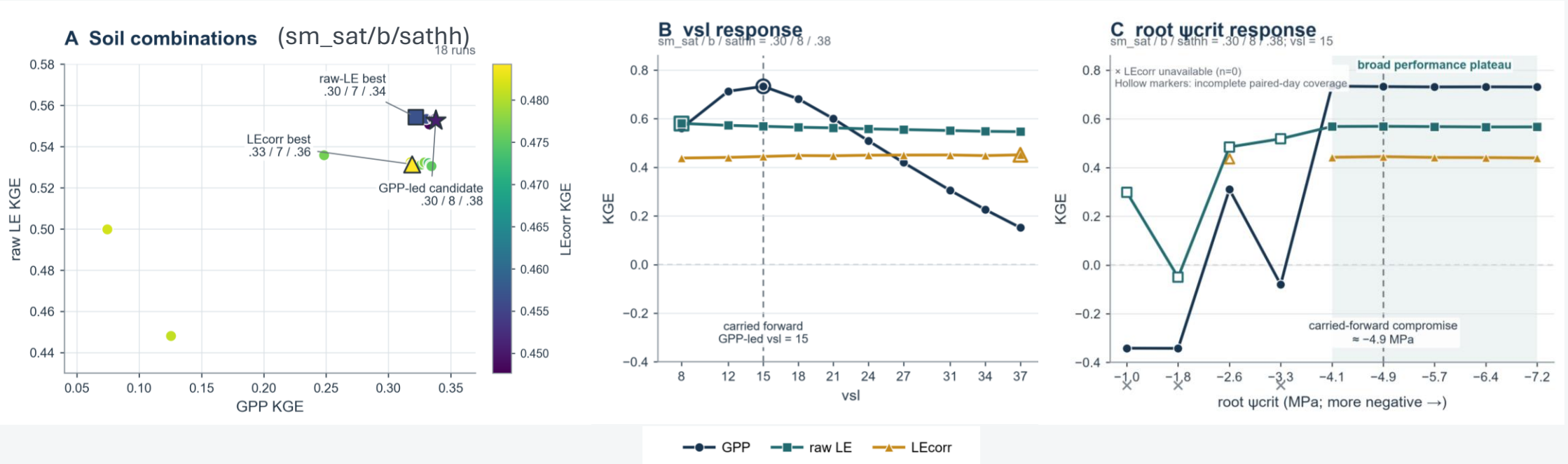
Selected structural candidate

GPP-prioritised

- STD: SF4L4 (4 layers, 0.7 m)
- PM: SF6L10 (6 layers, 0.5 m)

Result: soil, photosynthesis, hydraulic parameters

PM soil, vsl and rootψcrit | daily GPP, raw LE and LEcorr | 2000–2009 calibration period



GPP-best point, the raw-LE best point and the LEcorr best point are not same
GPP-prioritised selected:
sm_sat/b/sathh = 0.3/8/0.38

GPP is sensitive to vsl and peaks around 15
GPP-prioritised selected:
vsl = 15

Below roughly -4 MPa the metrics enter a broad plateau
GPP-prioritised selected:
root_psi_crit= -4.9

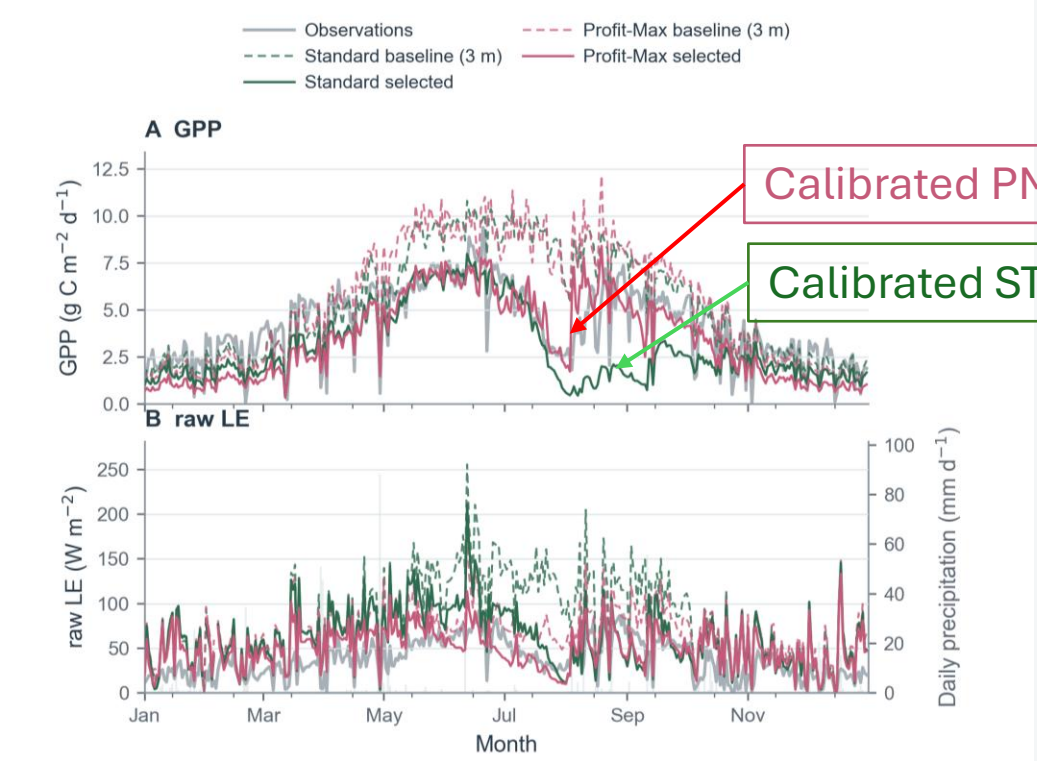
Summary: No single optimum across GPP, raw LE and LEcorr. Calibration target controls the selected parameters.

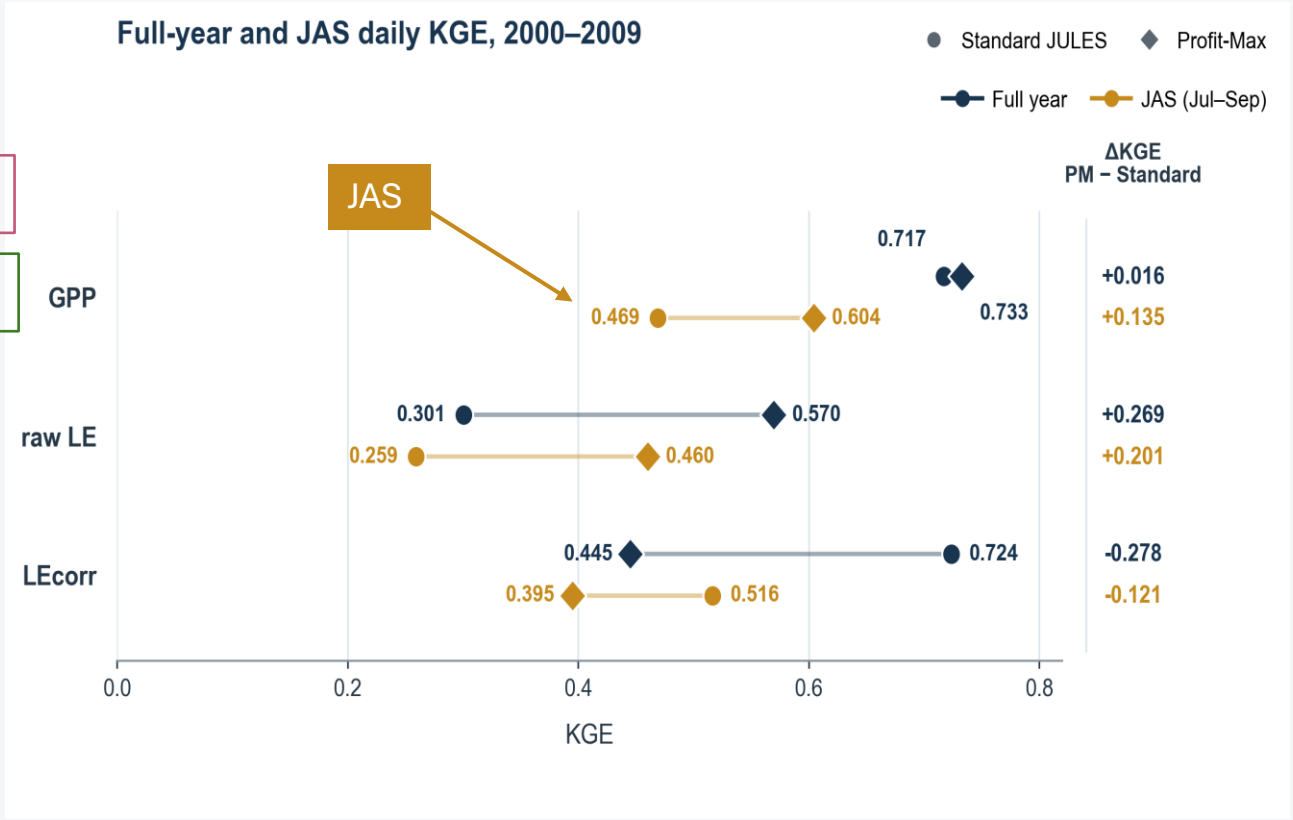
2 Does stomatal optimisation improve drought fluxes beyond calibration?

Result: Comparison between tuned STD and PM

Full-year and JAS | 2000–2009 | GPP, raw LE and LEcorr

2004 GPP and LE

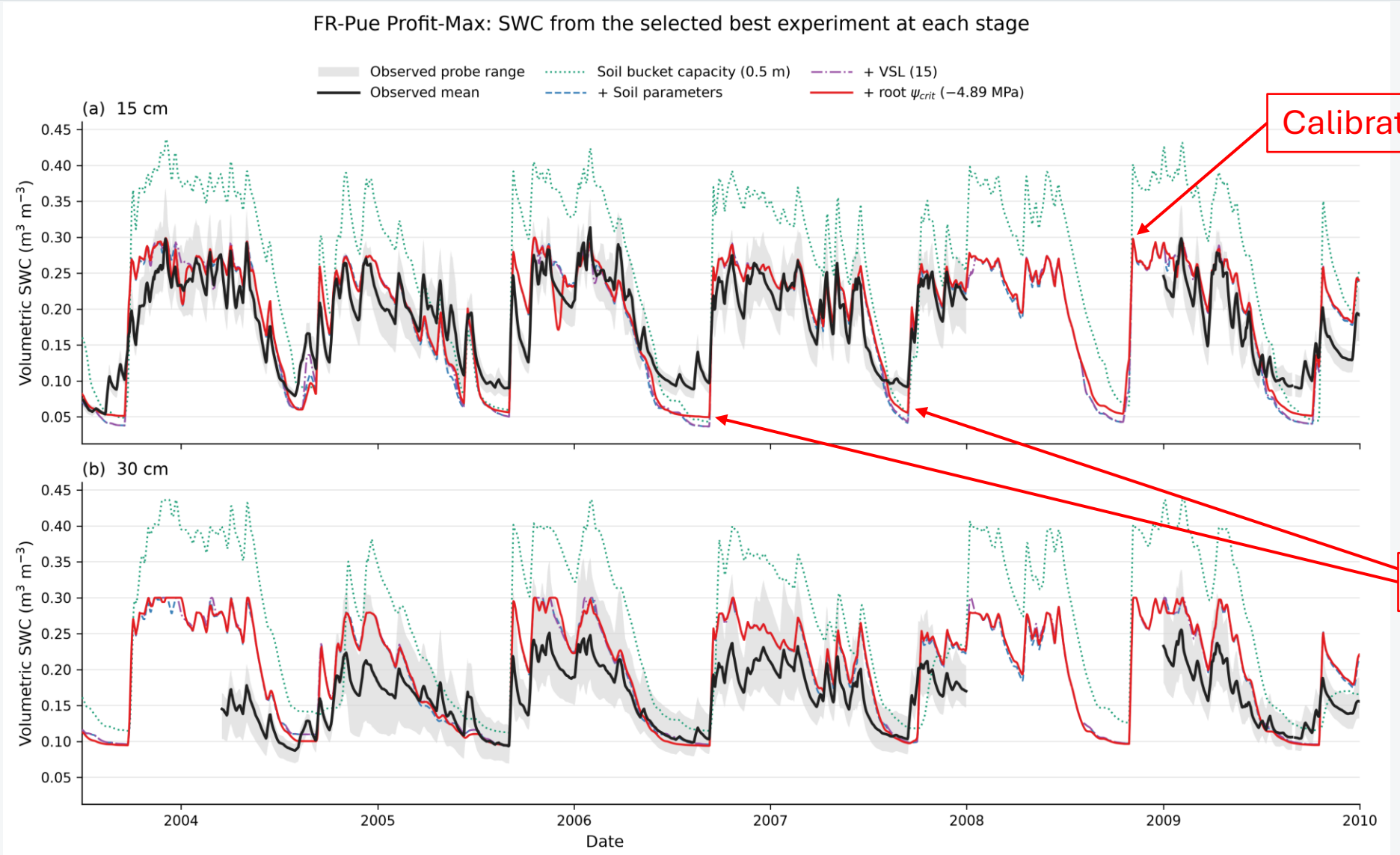




Summary: Profit-Max shows a GPP advantage in summer. Improving plant hydrology adds value on top of calibration.

3 **Are improvements achieved for the right physiological reasons?**

Result: Evaluation of simulated soil water content

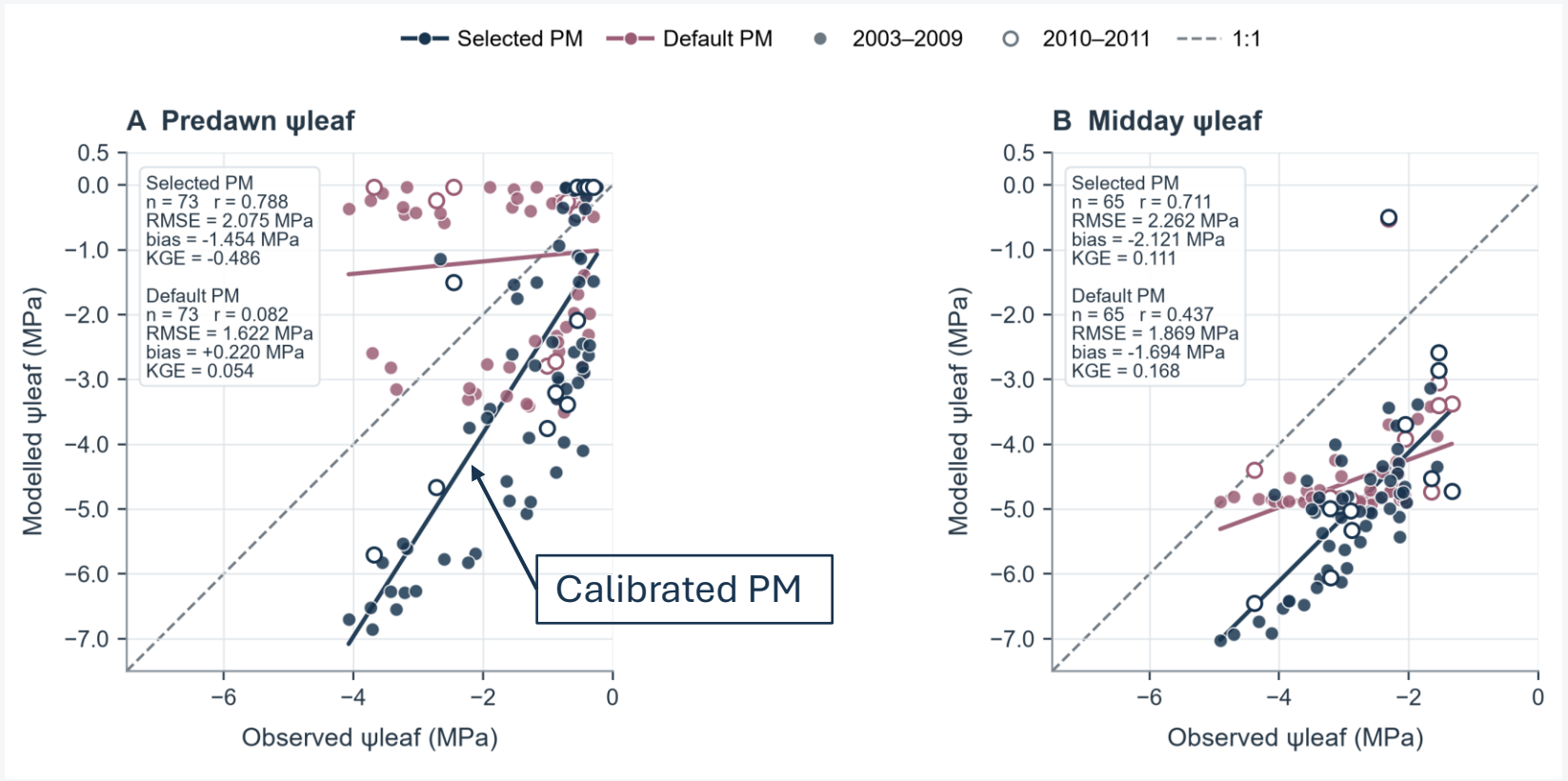


Summary: PM captures the SWC dynamics well, with a slight dry bias at 15 cm.

Result: Leaf-water-potential improvement

more negative:
stronger water stress

Selected versus default Profit-Max | historical ψleaf observations | 2003–2011



What improved?

- Predawn correlation improves strongly
  r: 0.082 → 0.788
- Midday correlation also improves
  r: 0.437 → 0.711

What did not improve?

- Predawn RMSE increases
  1.622 → 2.075 MPa
- Midday RMSE increases
  1.869 → 2.262 MPa
- **Bias becomes more negative**
  predawn +0.220 → −1.454 MPa
  midday −1.694 → −2.121 MPa

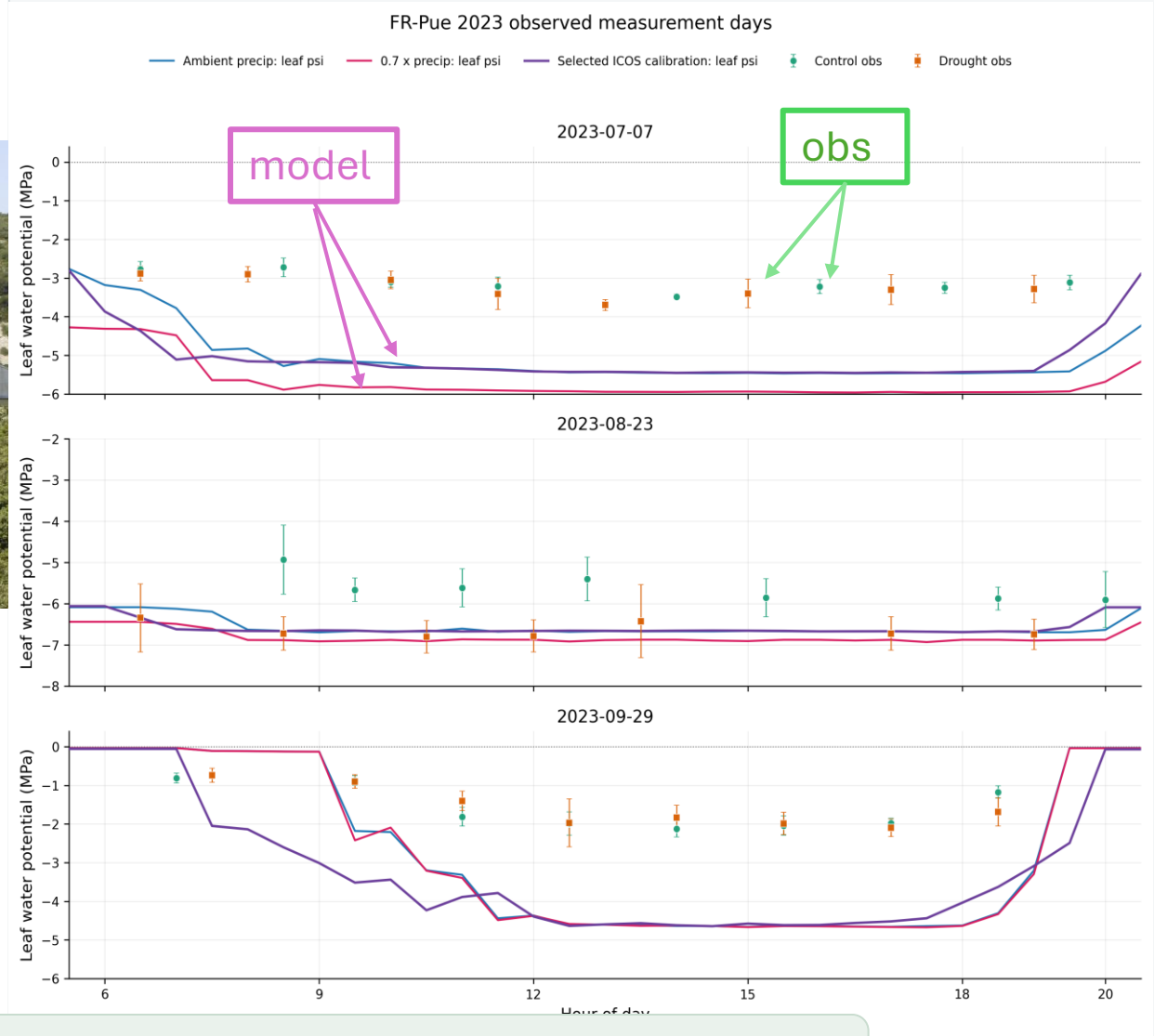
Summary

Calibrated PM improves ψleaf correlation, but stress magnitude is too strong

H1: LAI bias -> too much water being used? Rejected
H2: Esoil bias -> plant doesn't have enough water? Some evidence

4 Can the calibrated model predict a more severe drought?

Result: Leaf-water-potential in rain-exclusion treatment



Leading into drought ✗

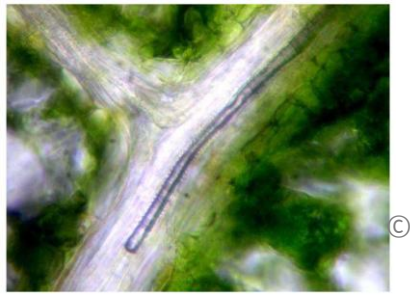
More intense drought period √

Recovery from drought ✗

Summary: When interpreting the treatment results, we should keep in mind that the model already tends to simulate leaf water potential values that are too negative.

5 Can hydraulic legacy effects improve drought predictions?

Result: New hydraulic legacy model with xylem impairment



Air blockage ("embolism") due to water stress

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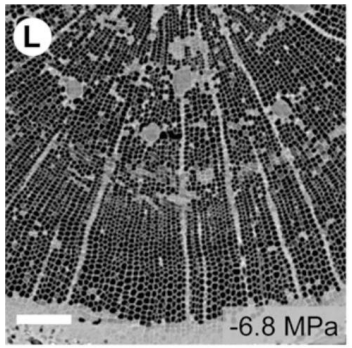
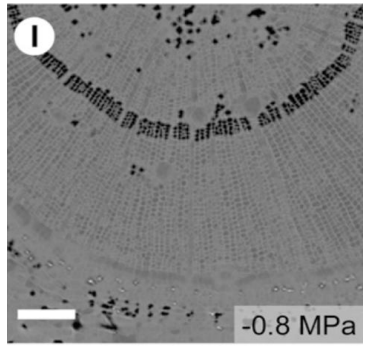
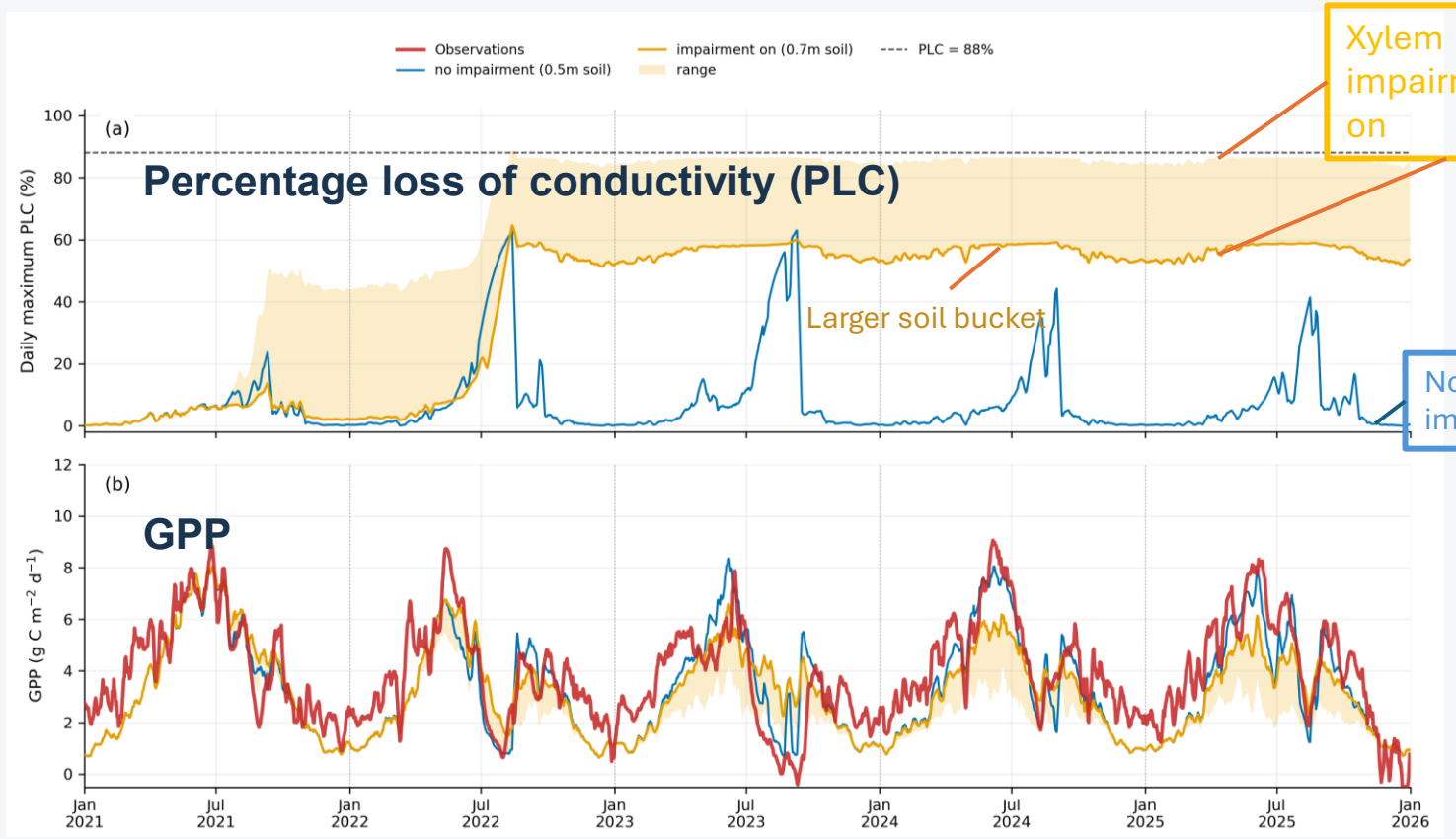


Spread of embolism (gas bubbles that block xylem conduits)

Choat et al. (2016) Plant Phys.



Branch dieback, even death



Summary:

- **Simulated PLC is highly sensitive to soil-bucket depth(a larger soil bucket reduces xylem damage) although parameter uncertainty remains.**
- **The model overestimates legacy damage because it does not regrowth of new xylem.**

Summary

1. **Structural calibration removes a major part of the baseline bias,**
   but no unique parameter optimum emerges – linked to LE bias

2. **Profit-Max improves summer GPP and raw LE,**
   but the advantage is not reproduced for LEcorr.

3. **SWC and ψleaf dynamics are broadly well represented**
   but ψleaf stress magnitude remains too strong.

4. **Transferability to intensified drought remains preliminary**
   and baseline-bias dependent.

5. **Hydraulic legacy can strongly amplify consecutive drought effects,**
   but the current implementation lacks the capacity to recovery (needs dgvm)

Thanks for listening.
— Questions?

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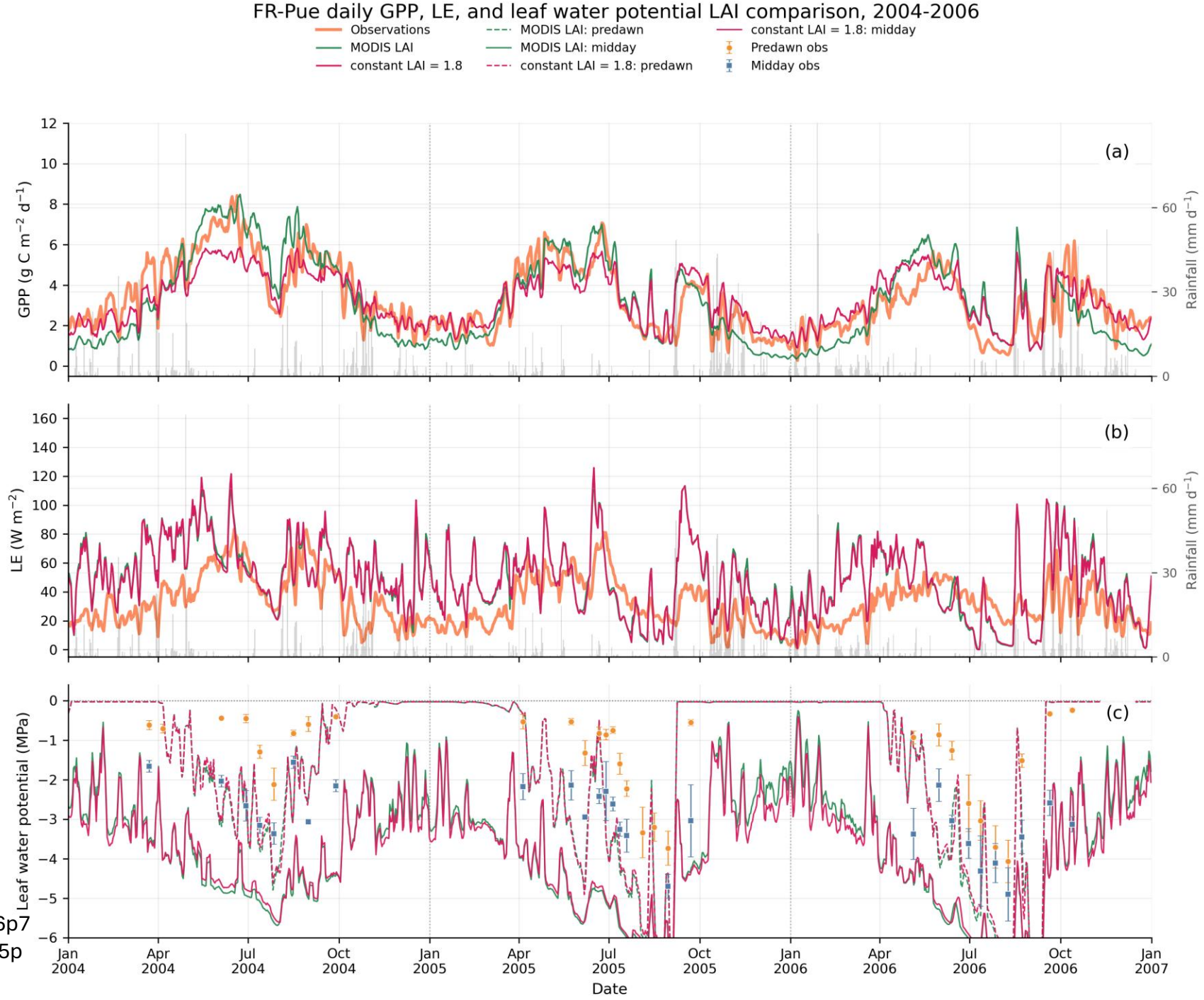

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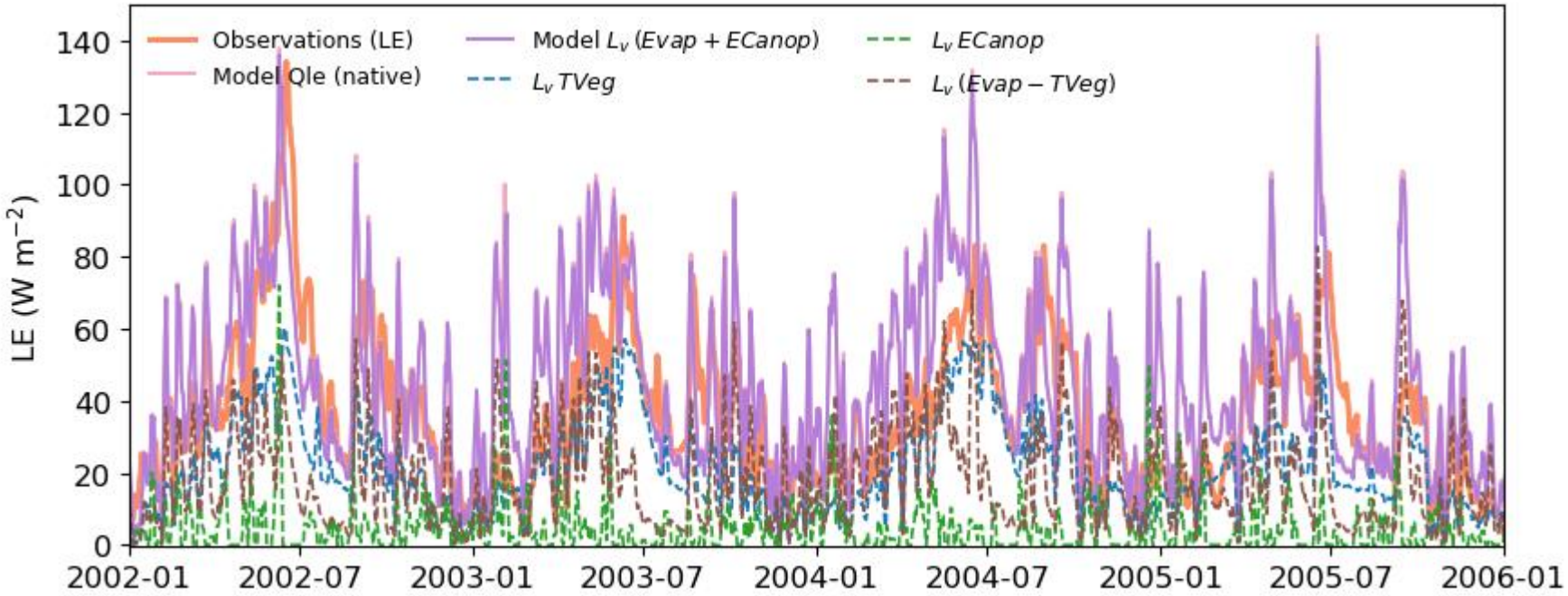

Bias: model LE – OBS LE

[corr] bias~TVeg : r = 0.360, p = 3.457e-79
[corr] bias ~ECanop : r = 0.381, p = 4.422e-89
[corr] bias ~ESoil : r = 0.654, p = 1.986e-312